# ANNEX I

# SEA LEVEL CHANGE ASSESSMENT FOR CENTRAL EVERGLADES PLANNING PROJECT

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# I EVALUATION OF THE EFFECT OF SEA LEVEL CHANGE ON THE CEPP

## I.1 INTRODUCTION

Per the guidance found in EC 1165-2-121, this paper provides a discussion of the effects of sea level change on the project area as well as on the restoration benefits anticipated to result from the implementation of the Central Everglades Planning Project (CEPP). The CEPP study area is shown in **Figure I-1**. Within the study area, the land elevation is relatively geologically static so this analysis of sea level change impacts covers only scenarios that include rising sea level conditions. The CEPP purpose is to improve the quantity, quality, timing, and distribution of water flows to the central Everglades (WCA 3 and ENP) while decreasing the magnitude and frequency of flows to the northern coastal estuaries (St. Lucie and Caloosahatchee estuaries via the C-43 and C-44). **Figure I-2** shows the project components for the tentatively selected plan (Alternative 4R). The Project will increase water delivery quantities past Tamiami Trail while maintaining water deliveries to the east of the L30 and L31-N canals necessary to maintain existing levels and quality of water supply for Miami-Dade County and Biscayne Bay and decreasing water delivery via the C-43 and C-44 to improve the ecological conditions of the St. Lucie and Caloosahatchee Estuaries. Elevations in the project area range from approximately +6.0 – 0.0 feet NAVD88 with the lowest elevations in the south and along the coastline. The low elevations mean that the project area will be impacted by future sea level rise (SLR) which is projected to be 2 to 6 ft over the next 100 years.

The ecosystem restoration benefits for this project are associated with the decreased frequency and magnitude of freshwater releases to the St. Lucie and Caloosahatchee Estuaries and the rehydration of freshwater wetlands and reduced salinity conditions in nearshore areas of Florida Bay downstream of Taylor and Shark River Sloughs.

## I.2 PROJECT AREA ECOLOGICAL SETTING

Portions of the project that are subject to potential impact from SLR are the Northern Estuaries which are located east and west of the Lake Okeechobee and the Everglades Wetlands / Nearshore. A short discussion of the valued ecological components located in these areas and how they are expected to be affected by SLR follows below.

### I.2.1 Northern Estuaries

Historically, freshwater flowed as sheetflow south from Lake Okeechobee, through the central part of the state to the estuaries. Water management activities in the past several decades have changed the magnitude, distribution, and timing of sheetflow throughout the Everglades landscape. In the north, water management changes have resulted in an increased magnitude and a change in the timing and distribution of flows to the northern estuaries (greater volume discharges during the wet season from a point source). Restoring historic flow volumes and timing to the northern estuaries will reestablish a salinity range most favorable to juvenile marine fish, shellfish, oysters and submerged aquatic vegetation (SAV) by reducing high volume and minimum discharge events to the estuary.

The effect of SLR on CEPP wetland and estuarine habitat will vary depending upon the location and elevation of the effected lands. In the northern estuaries, habitat coverage is represented by the area encompassing the preferred water depths (0.8-2.8 m) for the desired restored submerged aquatic vegetation species *Halodule wrightii* (Kenworthy and Fonseca 1996; Steward et al. 2005). **Figure I-3** and **Figure I-4** show oyster and sea grass habitat within selected portions of the St. Lucie and Caloosahatchee Estuaries.

Based on the topography and the existing infrastructure, inland impacts from SLR to the northern estuaries will be primarily restricted to increased water depths and saline conditions in the estuaries and canal systems, as the majority of the coastline is built out and protected by seawalls and other hardened structures. Light limitation is commonly the principal factor controlling the distribution of seagrass in the Northern Estuaries. Thus, seagrass beds typically terminate at a deep water edge where light is not sufficient to support photosynthesis. This deep water boundary or maximum depth limit can be quantified based on monitoring (Steward et al. 2005). As the Northern Estuaries deepen in response to rising sea level, the deep water edge of seagrass habitat throughout the basin will migrate upslope. In response to sea level rise, the relative depth of the deep water edge in each sub-basin or segment will not change. Suitable SAV habitat in the northern estuaries is expected to contract with SLR as the hardened shoreline restricts inward movement of the coastline and the creation of new suitable estuarine habitat. The result is increased water depths beyond the preferred range for the desired restored submerged aquatic vegetation species, *Halodule wrightii*. Habitat loss may be even higher in areas of the basin impaired by persistent pollutant loading and poor water quality.

Sea level rise during the next century will increase the exchange and circulation of Atlantic Ocean water with waters in the Caloosahatchee Estuary, Indian River Lagoon and the St. Lucie Estuary. The effect of this would be a more saline condition overall and a shift in salinity ranges and their location within the estuary. This shift could affect the location and health of most of the flora and fauna in the estuary including freshwater SAV, oysters, benthic communities and shoreline vegetation. In the Caloosahatchee River Estuary, a one dimensional hydraulic analysis was completed to determine the potential effects of sea level rise on the salinity distribution in the estuary (Hanks and Fitz 2005). The hydraulic analysis indicated that under current management strategies, a 0.9 m rise in mean sea level could result in a 4.5 psu increase at the regulatory compliance monitoring location at Ft. Myers which is 18 kilometers upstream of the mouth of the river at San Carlos Bay. Total inflow to the estuary would need to be increased from 14.2 $m^3$/s to 22.9 $m^3$/s or approximately 50 percent in order to meet current regulations. Additionally, a 0.9 m rise in sea level could reduce the rate of salinity reduction in the estuary under high freshwater flow conditions from 0.50 psu/day to 0.28 psu/day, with no observable effect on the rate of salinity increase under no flow conditions (Hanks and Fitz 2005).

Salinities and canal stages are also expected to increase in the St. Lucie and Caloosahatchee waterways (C-44, and C43 canals), increasing the probability of urban flooding and saltwater intrusion. On the other hand, the adverse effects of large freshwater releases from Lake Okeechobee to the northern estuaries that reduce salinities below the targets will be dampened to some extent by SLR.

### I.2.2 Everglades Wetlands/Nearshore

Sea level rise will affect the southern end of the project area from approximately Tamiami Trail south to Florida Bay. The effect of SLR on CEPP Everglades wetland and estuarine habitat will vary depending upon the location and elevation of the affected lands. SLR will cause saltwater to intrude into groundwater, damaging existing natural vegetation communities, drinking water supplies, etc. Hardened structures, buildout and sea walls will slow but not stop intrusion through highly porous bedrock. **Figure I-5** shows freshwater wetland habitat zones and indicator regions used to evaluate CEPP project benefits. Sea level rise over the next 50 years is not expected to affect habitat zones north of Tamiami Trail making ENP-N the northern most freshwater wetland habitat expected to be affected by SLR. The ENP-N, ENP-S, ENP-SE zones include both freshwater wetland habitat and saltwater wetland habitat. In general, the saltwater wetland habitat within these zones is considered to be the area encompassing the mean high water (0 – 2’) as an estimation of the mangrove zone. Freshwater wetland habitat is considered to be wetlands not subject to inundation under mean tide level (MTL) conditions. **Figure I-6** shows the saltwater wetland habitat zones as well as the nearshore habitat zones used to estimate project benefits in this area. Since the project is not expected to substantially affect existing water supply for Miami-Dade County and salinity conditions in nearshore areas of Biscayne Bay, the SLR impact analysis for estuarine habitat is limited to Florida Bay.

Changes in hydrology in the south end of the project area have resulted in the reduction of freshwater volume and duration of flows resulting in shortened wetland hydroperiods, reduced freshwater pooling along the sawgrass/mangrove ecotone, and disrupted sheetflow. The decreased fresh surface and ground water volumes and distribution through Taylor and Shark River Sloughs and the Lower East Coast to Florida Bay, the Lower Southwest Coast, and Biscayne Bay have resulted in a shift from the historic mesohaline conditions to hypersaline conditions in several nearshore areas. The CEPP project is intended to reverse some of these anthropogenic impacts by providing additional flows into northern Everglades National Park to rehydrate freshwater wetlands and enhance nearshore habitat. Restoring pre-drainage volume, distribution, and duration to the south will prolong the pooling of freshwater and increase volume and duration of freshwater to the estuaries (Davis et al. 2005). This increased volume and duration will decrease salinity in Florida Bay and the Lower Southwest Coast, driving the seagrass community and trophic web toward the pre-drainage condition (Rudnick et al. 2005). Maintenance of existing flow volumes and adjustments to timing and distribution to the Lower East Coast under CEPP is intended to result in the maintenance of existing ecological conditions in Biscayne Bay and quantity and quality of water available for Miami-Dade County water supply.

Based on the topography and the existing infrastructure, inland impacts related to SLR over the next 50 years will likely be limited within the southern portion of the Everglades landscape. The lack of hardened structures and/or natural topographic flow barriers along the southern coastal wetlands adjacent to Florida Bay and the Lower Southwest Coast will allow for largely unimpeded intrusion of saline waters inland as a function of SLR. It is anticipated the white zone habitat and mangrove forest will move north into the sawgrass habitat areas and the salt water front in the groundwater will move inland. Nearshore shallow estuarine habitat that is targeted for salinity improvement by this project will slowly move inland as MSL comes up. Peat soils may decompose and disappear as saltwater intrudes into the former freshwater grammanoid marsh areas magnifying the inland impacts of SLR and degrading water quality conditions in Florida Bay and the Lower Southwest Coast.

Many tidal creeks have already disappeared in coastal wetlands as a result of sedimentation and reduced flows. Restoring freshwater flows through the estuary will help maintain open watercourses; however, sea level rise is expected to modify the patterns of connectivity through coastal wetlands and create increased sediment loads (Davis et al. 2005). In addition to SLR, climate change may result in more extreme weather events. Increased temperatures and possible decreased rainfall will likely reduce peat accumulation rates, increase peat loss, and increase the susceptibility of freshwater wetlands to SLR. If SLR is accompanied by an increase in tropical storm intensity and frequency, the rate of soil accumulation may increase and partially offset higher MSL conditions. For example, Hurricane Wilma resulted in approximately 5 cm accumulation of sediment deposits in the mangrove zones in 2005 (Whelan, 2009).

Under higher rates of SLR, the increase in groundwater stages and surface water depths will result in a loss of flood protection for the southern portions of the project area. Increased salinity in the groundwater will result in water quality impacts to public and private water supply along the coastal portions of the project area. Changes to the open/close operating criteria at canal structures in the C-111 basin and others may be instituted as water managers attempt to counteract the effects of SLR on flood protection and salinity control. With no change to water management operations, agricultural lands north of the Everglades National Park panhandle will likely be abandoned and revert to freshwater wetland habitat since farming is likely to be uneconomical in the face of increased flooding and water quality issues.

Given the gentle slope of Taylor and Shark River Sloughs and other areas of the southern glades, SLR is expected to result in the translocation of estuarine nursery habitat northward as MSL increases. Man-made boundaries such as a levee or canal will limit the northward movement of the estuarine environment. Under the lower to moderate SLR projections, it is possible that SLR will actually provide a greater area of estuarine habitat than that presently. This depends upon how long it will take for former freshwater wetland habitat to become viable estuarine habitat. Factors affecting habitat transition include local scale topography, future changes to the landscape resulting from peat soil decomposition, storm event related sediment deposition, and changes to water quality.

## I.3 SLR IMPACT ANALYSIS

Corps planning guidance (EC 1165-2-211) calls for evaluating the effects of SLR under multiple scenarios. The multiple scenarios recommended include analysis of sea level rise at low, intermediate and high levels at 20, 50, and 100 years following the completion of project construction. The historic sea level rise as measured at the NOAA Key West tide station is 2.24 mm/yr. Sea level rise has been calculated by the Jacksonville District for the low, intermediate and high scenarios at 5 year intervals per EC 1165-2-212 guidance using the Corps Sea-Level Change Curve Calculator (http://www.corpsclimate.us/ccaceslcurves.cfm). The results of the SLR projections are shown graphically in **Figure I-7**. To assess the impact of SLR on project benefits which are computed under the assumption that 2022 is the initial year of project operations. Estimates of SLR from 1992 going forward and the net SLR with 2022 as the initial year of project operation are summarized in **Table I-1** for the 20 year, 50 year, and 100 year epochs. The net sea level rise going forward at 20, 50, and 100 years are estimated by using the SLR projection curves to subtract the sea level rise that has or will occur between 1992 and 2022. At the low end defined by the historic trend, the expected increased sea level is approximately 0.75 ft over the next 100 years. At the high end, the expected SLR over the next 100 years is 6.7 ft. Note that the Corps climate change guidance does not address change beyond 2100 so estimates of sea level change at 2122 should be used with caution.

### I.3.1 Methodology for Assessing Impacts to Project Benefits

The ecological benefits associated with this project are the enhancement of northern estuarine freshwater flow conditions, extension of freshwater wetland hydroperiod, and the improvement (reduction) or maintenance of salinity conditions in the nearshore areas in Florida Bay and downstream of Taylor and Shark River Sloughs. **Table I-2** shows the estimate habitat function (in acres) for the existing condition baseline (ECB) and the net habitat improvement (acres of lift) for the future without condition (FWO) and the with-project condition, Alternative 4R2 (ALT4R2). In this table, the ecological benefit zones that are likely to be impacted by sea level rise are highlighted in pink, yellow and orange. The pink highlighted benefit zones are northern estuary habitat areas that will be subject to sea level rise impacts such as increased salinity and increased depth. These habitat zones are not expected to translocate because of shoreline hardening and natural topographic conditions. The yellow highlight benefit zones are freshwater wetland habitat areas where sea level rise is expected to reduce the area of functional freshwater wetlands due to changes in salinity, increased depth, and loss of peat soils. The orange highlighted benefits zones are those Florida Bay nearshore estuarine habitat zones that are expected to migrate inland as a result of sea level rise due to changes in salinity and increased depth. While the habitat benefits for Florida Bay are expected to be impacted by SLR, they were assumed to be constant in this analysis. In other words, for this analysis loss of estuarine benefits in the Florida Bay zones shown in **Figure I-6** are assumed to be made up by gains in estuarine habitat as freshwater habitat in the ENP-N, ENP-S, ENP-SE zones convert to saltwater habitat. Habitat zones north of Tamiami Trail which acts as a partial barrier are assumed to be unaffected by SLR in this analysis so the benefits estimated for these areas (Water Conservation Areas 1, 2, 3) are not adjusted for SLR impacts. Overall, approximately 50% of the expected project benefits are assumed to be either not impacted by SLR because they will occur in areas not subject to SLR or they are estuarine benefits located in Florida Bay and are expected to not diminish as additional upland areas convert from freshwater to saline habitat.

**Table I-1. Total and Net Sea Level Change at Three Epochs for Historic, Intermediate, and High Rate Projections.**

| | | Total Sea Level Change Relative to 1992 Base Epoch Year (Key West Tidal Gauge) | | | Net Sea Level Change from 2022 Project Start Date | | |
|---|---|---|---|---|---|---|---|
| Time Epoch | Date | Low Projection (Based on Historic Rate at Key West) | Intermediate (Based on NRC Curve I) | High (Based on NRC Curve III) | Low Projection (Based on Historic Rate at Key West) | Intermediate (Based on NRC Curve I) | High (Based on NRC Curve III) |
| | | (ft) | (ft) | (ft) | (ft) | (ft) | (ft) |
| 0 | 2022 | 0.22 | 0.30 | 0.55 | | | |
| 20 | 2042 | 0.36 | 0.58 | 1.29 | 0.14 | 0.28 | 0.7 |
| 50 | 2072 | 0.58 | 1.15 | 2.95 | 0.36 | 0.85 | 2.4 |
| 100 | 2122 | 0.94 | 2.44 | 7.2 | 0.72 | 2.1 | 6.7 |

**Table I-2. Estimated Habitat function (in acres) for ECB and Net Habitat Lift for FWO and ALT 4R2**

| | | Change from ECB Condition | |
|---|---|---|---|
| **Project Region (Zone)** | **ECB** | **FWO** | **ALT4R2** |
| Caloosahatchee Estuary (CE-1) | 2839 | 31231 | 36199 |
| St Lucie Estuary (SE-1) | 2099 | 300 | 6148 |
| | | | |
| Total Northern Estuaries | 4938 | 31531 | 42347 |
| | | | |
| Northeast WCA 3A (3A-NE) | 44451 | -14817 | 46921 |
| WCA 3A Miami Canal (3A-MC) | 32847 | -5474 | 21899 |
| Northwest WCA 3A (3A-NW) | 30970 | -704 | 23228 |
| Central WCA 3A (3A-C) | 108414 | -2745 | 2745 |
| Southern WCA 3A (3A-S) | 69247 | -824 | -824 |
| WCA 3B (3B) | 55697 | -6855 | 3428 |
| Northern ENP (ENP-N) | 57557 | -2503 | 41290 |
| Southern ENP (ENP-S) | 124068 | 2386 | 45332 |
| Southeast ENP (ENP-SE) | 79711 | 1351 | 4053 |
| | | | |
| Total Greater Everglades | 602962 | -30185 | 188072 |
| | | | |
| Florida Bay West (FB-W) | 23693 | -3159 | 17375 |
| Florida Bay Central (FB-C) | 9,025 | -820 | 5744 |
| Florida Bay South (FB-S) | 16614 | -1955 | 11727 |
| Florida Bay East Central (FB-EC) | 21984 | -1759 | 12311 |
| Florida Bay North Bay (FB-NB) | 2154 | -126 | 507 |
| Florida Bay East (FB-E) | 9440 | -755 | 378 |
| | | | |
| Total Florida Bay | 82910 | -8574 | 48042 |
| | | | |
| Total All Regions | 690810 | -7,228 | 278461 |

The evaluation of the project benefits included an estimate of the timeline in which habitat lift would be realized over the project life span. **Table I-3** shows the percent of benefits achieved from year zero through year 100 for the project as estimated for the three habitat regions (northern estuaries, freshwater wetlands, southern estuary). Since benefits increase over time and SLR impacts also increase over time, a histogram of benefits typically has a rising limb followed by falling limb as SLR impacts accrue. Using this timeline for benefit accrual, the 50-year average project benefits are 227,262 habitat units which is about 84 percent of the expected net project benefits of 271,931 habitat units shown in **Table I-2**.

Changes to the area of freshwater wetland were used as an indicator of how these freshwater wetland benefits are likely to be impacted by SLR. To assist in the evaluation of the likely effects of sea level rise on project benefits, the areas where benefits are expected to occur were projected onto flood prediction maps generated under different mean tide level (MTL) conditions. For this assessment, Florida Bay bathymetric data were projected onto the NAVD88 datum using the National Oceanic and Atmospheric Administration (NOAA) VDatum software program. This software is designed to convert different horizontal/vertical references into a common reference level which is necessary when creating maps that incorporate both terrestrial and bathymetric data. A more conservative approach to this analysis would be to use Mean Higher High Water (MHHW) rather than MTL as the reference since ecological systems are affected by changes in salinity which are strongly influenced by MHHW. This was not done because the analysis considered full and immediate loss of peat soils as a conservative estimate of the extent of inland impact. In reality it may take several decades for peat soils to completely collapse.

The mapping of the likely freshwater wetland and estuarine benefit zones were created using difference mapping techniques for the ALT4R2 scenario overlaid with SLR projections of 0', +1', +2', +3', +4' and +5'. For the Everglades Freshwater wetlands (ENP-N, ENP-S, ENP-SE), the total area suitable for freshwater habitat was estimated using the GIS projection of mean tidal level (MTL) at 1 ft increments of sea level rise and topography developed from top of peat survey data or top of rock survey data. Freshwater wetland habitat area loss was then estimated by taking the difference between the existing freshwater wetland habitat function acreage and the projected habitat function acreage for each SLR scenario and time point. Two estimates for each timeframe (20, 50, and 100 years) and SLR scenario (Historic, Intermediate, High rate) were evaluated. One estimate, denoted as "Low", represents expected benefit reduction if peat soils are intact. The other estimate, denoted as "High", represents the expected benefit reduction if peat soils are destroyed by sea level rise related salinity.

The CEPP project will rehydrate portions of the Everglades freshwater wetlands. The additional project provided water will increase groundwater stages and provide more freshwater which should counteract some of the impacts from sea level rise. To determine the maximum reduction in benefit loss due to increased freshwater flows, the net increase in sea level rise was adjusted by subtracting up to 100 percent of the median increase in surface water stage from the estimated increase in sea level rise calculated for the historic, intermediate, and high rate SLR for the 20, 50, and 100 year periods. **Table I-4** shows the median increase in surface water stage for IR129, IR131, and IR133 which are located in ENP-N, ENP-S, and ENP-SE, respectively.

For the northern estuaries SLR benefit impact assessment, the total area suitable for sea grass habitat was estimate for each 1 ft increment of sea level rise using 2.6 to 9.2 feet as the optimum depth range for sea grass. Estimates of benefit loss for the northern estuaries were computed using a ratio of suitable habitat acreage under SLR conditions to suitable habitat acreage without SLR. This methodology does not take into account changes to salinity or light transmittance that both affect sea grass habitat suitability.

**Table I-3. Timeline for Achieving Project Benefits by Habitat Region**

| Percent of Benefits Achieved Over Time | | | | | | |
|---|---|---|---|---|---|---|
| | Year 5 | Year 10 | Year 15 | Year 20 | Year 50 | Year 100 |
| Northern Estuaries | 0% | 50% | 75% | 100% | 100% | 100% |
| Greater Everglades | 25% | 50% | 75% | 100% | 100% | 100% |
| Florida Bay | 17% | 33% | 50% | 75% | 100% | 100% |

**Table I-4. Median Change in Surface Water Stage within Everglades Freshwater Wetlands South of Tamiami Trail**

| Indicator Region | Median Change in Surface Water Stage (ft) for ALT4R2 vs ECB/FWO |
|---|---|
| | (ft) |
| IR129 (ENP-N) | 0.6 |
| IR131 (ENP-S) | 0.25 |
| IR133 (ENP-SE) | -0.2 |

### I.3.2 Estimated Impact to Project Benefits

**Table I-5** shows the percent reduction in productive habitat for each zone potentially impacted by salinity. The difference between the “low” and “high” estimates is due to the assumption that the peat soils will remain intact (Low) or the peat soils will be lost and the land elevation will match the top of rock survey (High). The assumption that peat soils will be affected by SLR is critical to the estimation of habitat loss under all three of the sea level rise scenarios and timeframes since it appears that freshwater wetland habitat losses double if peat soils are destroyed by SLR. This is true for all scenarios except the 100 year – high rate scenario where losses of habitat are extensive regardless of whether the peat soils remain or not.

**Table I-6** shows the net change in habitat loss due to SLR in comparison to FWO conditions after accounting for changes in the distribution and quantity of freshwater flows that will occur with the CEPP. Specifically, the difference in habitat loss shown in this table is attributable to the assumption that increases or decreases in surface water stages will alter the impact of sea level rise. Since no increase in surface water stages within the Caloosahatchee and St. Lucie Inlet is expected with CEPP, habitat loss for FWO is assumed to be similar to the with-project condition (ALT4R2). For ENP-N, ENP-S, and ENP-SE, the net increase in sea level rise was adjusted based upon the median difference between surface water stages with the project and without the project as determined at the indicator regions shown in **Table I-4**. For the northern everglades wetlands, ALT4R2 is expected to increase the surface water stage by 0.6 ft. For the southern everglades ALT4R2 is expected to increase the surface water stage by 0.25 ft. For the southeastern everglades, ALT4R2 is expected to decrease surface water stages by 0.2 ft. For the ENP-N habitat zone, there is little difference between the FWO and ALT4R2 except under high rate SLR conditions particularly at the 100 year time point. This is largely because the ENP-N habitat zone is expected to be largely un-impacted by SLR except in the distant future or under extreme SLR conditions. The increase in surface water stages under ALT4R2 for the ENP-S habitat zone may reduce freshwater wetland habitat loss by 0 to 14 percent depending upon the SLR scenario, timeframe, and topography assumption. Relative to FWO, ALT4R2 performs best under the historic and intermediate SLR scenarios for ENP-S. The difference between FWO and ALT4R2 under the high rate scenario is no larger than 6 percent which is likely due to the fact that the high rate scenario SLR overwhelms the limited increase in surface water stage under ALT4R2. The decrease in surface water stages under ALT4R2 for the ENP-SE habitat zone may increase freshwater wetland habitat loss by up to 12 percent depending upon the SLR scenario, timeframe, and topography assumption. The increased loss of habitat in ENP-SE under ALT4R2 is the result of reduced flows to Taylor slough relative to FWO conditions.

**Table I-5. Range of Habitat Loss for ALT 4R2**

| | Percent of Available Habitat Lost | | | | | |
|---|---|---|---|---|---|---|
| | Historic | | Intermediate | | High | |
| | Low | High | Low | High | Low | High |
| 20-year Impact | | | | | | |
| Caloosahatchee SAV | | 1% | | 2% | | 7% |
| St. Lucie Inlet SAV | | 3% | | 8% | | 22% |
| ENP N Freshwater Wetlands | 0% | 0% | 0% | 0% | 0% | 0% |
| ENP S Freshwater Wetlands | 1% | 2% | 5% | 9% | 11% | 21% |
| ENP SE Freshwater Wetlands | 9% | 20% | 12% | 27% | 21% | 49% |
| 50-year Impact | | | | | | |
| Caloosahatchee SAV | | 2% | | 5% | | 32% |
| St. Lucie Inlet SAV | | 8% | | 20% | | 38% |
| ENP N Freshwater Wetlands | 0% | 0% | 0% | 0% | 0% | 26% |
| ENP S Freshwater Wetlands | 3% | 5% | 15% | 28% | 39% | 68% |
| ENP SE Freshwater Wetlands | 15% | 34% | 27% | 60% | 53% | 69% |
| 100-year Impact | | | | | | |
| Caloosahatchee SAV | | 4% | | 15% | | 44% |
| St. Lucie Inlet SAV | | 15% | | 28% | | 58% |
| ENP N Freshwater Wetlands | 0% | 0% | 0% | 14% | 58% | 100% |
| ENP S Freshwater Wetlands | 14% | 26% | 41% | 66% | 100% | 100% |
| ENP SE Freshwater Wetlands | 25% | 56% | 52% | 69% | 100% | 100% |

*Low – Estimate computed using top of peat soil topographic survey.
*High – Estimate computed using top of rock topographic survey.

**Table I-6. Net Change in Habitat Loss Due to SLR**

| Change in Habitat Loss Due to the Project (FWO - ALT4R2) | | | | | | |
|---|---|---|---|---|---|---|
| | Difference in Percent Habitat Lost | | | | | |
| | Historic | | Intermediate | | High | |
| | Low | High | Low | High | Low | High |
| 20-year Impact | | | | | | |
| Caloosahatchee | | 0% | | 0% | | 0% |
| St. Lucie Inlet | | 0% | | 0% | | 0% |
| ENP N Freshwater Wetlands | 0% | 0% | 0% | 0% | 0% | 0% |
| ENP S Freshwater Wetlands | 3% | 6% | 3% | 6% | 8% | 14% |
| ENP SE Freshwater Wetlands | -5% | -12% | -5% | -12% | -5% | -12% |
| 50-year Impact | | | | | | |
| Caloosahatchee SAV | | 0% | | 0% | | 0% |
| St. Lucie Inlet SAV | | 0% | | 0% | | 0% |
| ENP N Freshwater Wetlands | 0% | 0% | 0% | 0% | 0% | 14% |
| ENP S Freshwater Wetlands | 8% | 15% | 10% | 18% | 4% | 4% |
| ENP SE Freshwater Wetlands | -6% | -13% | -6% | -11% | -5% | -1% |
| 100-year Impact | | | | | | |
| Caloosahatchee SAV | | 0% | | 0% | | 0% |
| St. Lucie Inlet SAV | | 0% | | 0% | | 0% |
| ENP N Freshwater Wetlands | 0% | 0% | 0% | 24% | 14% | 0% |
| ENP S Freshwater Wetlands | 8% | 15% | 0% | 6% | 0% | 0% |
| ENP SE Freshwater Wetlands | -6% | -13% | -5% | -1% | 0% | 0% |

**Table I-7** shows the estimated total project habitat units for the 20, 50, and 100 year timeframes under the three SLR scenarios as well as the 50-year average net benefits for each scenario for ALT4R2. Results are shown for the "Top of Rock" and "Top of Peat" topographic survey assumptions as well as with-hydrologic adjustment and without-hydrologic adjustment. **Table I-8** shows the percent of total habitat lost at 20, 50, and 100 years under the scenario that additional ALT4R2 CEPP flows counteract SLR impacts and that all of the peat soils within the MTL affected area are lost. In terms of total habitat units, the SLR scenario assumptions result in a maximum of 8 percent reduction in total habitat units at the 20-year timeframe, 22 percent difference in habitat units at the 50-year timeframe, and up to 39 percent difference in habitat units at the 100-year timeframe. However from **Table I-7**, the 50-year average net project habitat lift does not vary more than a couple percent across any of the SLR rate scenarios or due to the assumptions for peat soils or project related hydrology. The net project habitat lift shown in **Figure I-8** indicates very little reduction in lift for the historic and intermediate SLR scenarios at year 50 and a reduction in Year 50 lift for the High Rate Scenario of approximately eight percent when compared to the no SLR scenario. However, in total habitat terms (**Figure I-9**), the High Rate Scenario indicates 22 percent reduction of the habitat units at Year 50 when compared to the no-SLR scenario. The impact of SLR on net benefits is less than that of total habitat units because SLR impacts will affect FWO habitat conditions in a fashion similar to the with-project condition.

As a simplification, this analysis assumed no gain or loss in estuarine habitat due to uncertainty in the rate at which former freshwater wetland acreage converts to functional estuarine habitat. Within the approximately 470,000 acres of Florida Bay considered in the CEPP benefit analysis, approximately 200,000 acres of the bay are less than 2 ft deep with approximately 100,000 of those acres less than 1 ft deep. **Table I-9** shows the available estuarine acreage defined as areas inundated up to 2 ft will greater for the first two feet of sea level rise; however, the functionality of this additional estuarine habitat will depend upon the rate at which the freshwater wetlands convert. With three or more feet of sea level rise, the available habitat is less than the acreage at present meeting the 0 to 2 ft depth criteria. Based on the three SLR scenarios (Historic, Intermediate, Low), an additional two feet of SLR is likely to occur between 50 and approximately 200 years into the future.

**Figure I-10** shows that total habitat function is higher with CEPP in place under any SLR scenario and timeframe when compared to the FWO condition. The ability of the CEPP project to provide higher habitat functionality when compared to the FWO is a result of two factors: 1) the peak habitat functionality with CEPP is significantly greater than the FWO condition which means that proportional loss due to SLR affects both the CEPP and FWO conditions fairly equally, and 2) increased freshwater flows with CEPP reduce the loss of freshwater habitat within Everglades National Park that would occur under the FWO condition.

**Table I-7. Estimated Habitat Units (in acres) at 20, 50, and 100 Year Timeframes and 50-yr Avg Net Habitat Benefits for Three SLR Rate Scenarios for ALT4R2.**

| No Sea Level Rise | | | | | |
|---|---|---|---|---|---|
| | Total Habitat Units | | | | Average |
| Scenario | ECB | 20 YR | 50 YR | 100 YR | Net |
| TOP/ No Stage Adjustment | 690,810 | 957,261 | 969,271 | 969,271 | 225,535 |
| **Historic Rate of Sea Level Rise** | | | | | |
| | Total Habitat Units | | | | Average |
| Scenario | ECB | 20 YR | 50 YR | 100 YR | Net |
| TOP / No Stage Adjustment | 690,810 | 946,913 | 941,561 | 913,237 | 222,932 |
| TOR / No Stage Adjustment | | 937,316 | 915,771 | 861,058 | 220,880 |
| TOP / 50% Stage Adjustment | | 947,327 | 946,186 | 917,916 | 224,536 |
| TOR / 50% Stage Adjustment | | 937,179 | 923,378 | 868,754 | 223,099 |
| TOP / Full Stage Adjustment | | 947,741 | 950,811 | 922,595 | 226,140 |
| TOR / Full Stage Adjustment | | 937,032 | 930,966 | 876,449 | 225,312 |
| **Intermediate Rate of Sea Level Rise** | | | | | |
| | Total Habitat Units | | | | Average |
| Scenario | ECB | 20 YR | 50 YR | 100 YR | Net |
| TOP / No Stage Adjustment | 690,810 | 936,823 | 905,602 | 852,141 | 220,146 |
| TOR / No Stage Adjustment | | 918,231 | 846,825 | 745,348 | 215,708 |
| TOP / 50% Stage Adjustment | | 937,238 | 911,042 | 850,065 | 222,003 |
| TOR / 50% Stage Adjustment | | 918,102 | 855,774 | 761,080 | 218,344 |
| TOP / Full Stage Adjustment | | 937,652 | 916,805 | 847,861 | 223,960 |
| TOR / Full Stage Adjustment | | 917,955 | 867,652 | 777,786 | 221,887 |
| **High Rate Sea Level Rise** | | | | | |
| | Total Habitat Units | | | | Average |
| Scenario | ECB | 20 YR | 50 YR | 100 YR | Net |
| TOP / No Stage Adjustment | 690,810 | 906,777 | 841,237 | 622,771 | 214,915 |
| TOR / No Stage Adjustment | | 861,795 | 734,394 | 595,216 | 202,910 |
| TOP / 50% Stage Adjustment | | 911,079 | 842,743 | 622,771 | 217,431 |
| TOR / 50% Stage Adjustment | | 868,871 | 743,866 | 595,216 | 208,848 |
| TOP / Full Stage Adjustment | | 915,382 | 843,739 | 636,458 | 219,790 |
| TOR / Full Stage Adjustment | | 875,948 | 754,584 | 595,216 | 215,172 |

**Table I-8. Percent Total Habitat Loss at 20, 50, and 100 Years, Assuming Top of Rock, and Full Stage Adjustment for ALT4R2.**

| Percent Total Habitat Lost Due to SLR | | | |
|---|---|---|---|
| **Sea Level Rise Scenario** | 20 YR | 50 YR | 100 YR |
| **Historic SLR** | 2% | 4% | 10% |
| **Intermediate SLR** | 4% | 10% | 20% |
| **High Rate SLR** | 8% | 22% | 39% |

**Table I-9. Change in Everglades Estuarine Habitat Due to Sea Level Rise for ALT4R2.**

| Change in Estuarine Habitat | | | | | | |
|---|---|---|---|---|---|---|
| | | Increase in Sea Level Rise (ft) | | | | |
| | | **0** | **1** | **2** | **3** | **5** |
| | | **Acres of Estuarine Habitat Meeting Depth Criteria** | | | | |
| **Southern ENP (ENP-S)** | | | | | | |
| | **0 to 2 ft deep** | 4,035 | 34,912 | 58,694 | 53,354 | 2,100 |
| | **> 2 ft deep** | - | 191 | 4,035 | 72,972 | 85,299 |
| **Southeast ENP (ENP-SE)** | | | | | | |
| | **0 to 2 ft deep** | 9,241 | 72,119 | 87,318 | 50,197 | 83,700 |
| | **> 2 ft deep** | 345 | 853 | 9,636 | 35,102 | 126,326 |
| **Existing Florida Bay Habitat** | | | | | | |
| | **0 to 1 ft deep** | 71,970 | - | | | |
| | **1 to 2 ft deep** | 31,152 | 71,970 | | | |
| | **> 2 ft deep** | 287,164 | 318,316 | 390,286 | 390,286 | 390,286 |
| **Total Estuarine Habitat** | | | | | | |
| | **0 to 2 ft deep** | 116,398 | 179,001 | 146,012 | 103,551 | 85,800 |
| | **> 2 ft deep** | 345 | 73,014 | 13,671 | 108,074 | 211,625 |

### I.3.3 Discussion

The estimation of benefit loss for the Everglades is based on the GIS mapping analysis presented in **Figure I-11** through **Figure I-14**. In these figures for the 1 ft and 2 ft SLR scenarios, the grey area represents the probable limits of the freshwater habitat, the light blue areas are transitional wetlands with some impact from increased salinity, and the dark blue area represents areas that are greater than 2 ft deep and likely to be fully estuarine habitat. The maps with complete peat loss show that SLR impacts will extend inland several miles particularly in Shark River Slough which presently has thick peat soils.

Loss in freshwater wetland benefits to ENP-S and ENP-SE will occur in the southern portions of the regions as increased salinity causes a shift from freshwater vegetation to saline tolerant vegetation.

These newly created saltwater wetland habitat will result in the expansion of the Florida Bay North, West, Central, East-Central, and East estuarine zones. Benefit gain in the Florida Bay zone is dependent on the rate of landscape transformation from a mangrove/gramminoid marsh community to a nearshore estuarine environment and may not be completely realized 20 years post-saltwater inundation. This results of this analysis assumed that estuarine habitat remains constant over the period of the analysis though Table 9 shows that available estuarine habitat area will increase given up two feet of SLR. This additional estuarine acreage is not counted in the benefits assessment because it is difficult to predict how quickly and to what extent it will be functional. Given the gentle slope of the topography of Taylor Slough and Shark River Slough and the lack of man-made barriers such as levees or canals, it is unlikely that mesohaline and oligohaline nearshore areas will be completely eliminated by SLR under any scenario in 20 years. However, with high SLR projections in excess of 2 ft there will be a reduction in the 0 to 2 ft estuarine habitat and thus less available area where salinity conditions may be optimal for some mesohaline and oligohaline species. This analysis also does not account for the potential reduction in the severity and duration of hypersaline conditions in Joe Bay, Barnes Sound, Manatee Bay, and Florida Bay proper that results from increased exchange of bay water with ocean water.

**Figure I-15** through **Figure I-18** show potential aquatic vegetation habitat under 0 ft and 2 ft of SLR. These maps show much greater potential SAV coverage than the existing aquatic vegetation coverage maps (**Figure I-3** and **Figure I-4**). This difference is likely due to the water quality and substrate limitations that are not explicitly considered in the analysis methodology used to develop the potential SAV habitat maps.

## I.4 UNCERTAINTY DISCUSSION

As with the predictions of future rates of SLR, there is uncertainty in the estimation of effects to project related ecosystem benefits due to the accuracy and reliability of the datasets used in this analysis. Two elevation scenarios were used to evaluate SLR impacts to the Everglades: existing topography, and a topographic change due to the degradation and collapse of the existing peat soils in the southern portion of the Project. This based on the understanding that saltwater interactions with peat soils can cause them to collapse resulting in a decrease in elevation allowing for greater spatial impacts inland from SLR. These topographic datasets are known to be accurate to within plus or minus 0.5 ft. In addition to these sources of topographic uncertainty, the benefitted area mapping is based upon the Glades-LECSA Regional Simulation model output that has a surface water stage prediction accuracy estimated at 0.5 ft.

The analysis assumed that Tamiami Trail and the L-29 levee will serve as a barrier to SLR impacts within WCA-3A/B at least the next 100 years. This assumption is reasonable for the historic and intermediate SLR scenarios. Under the high SLR rate scenario, impacts to WCA-3A/B are likely to occur within the next 50 to 100 years, particularly if project features such as the degradation of L-29 levee are not modified to prevent saline waters from traveling north of Tamiami Trail.

Estimates of benefit loss for the Caloosahatchee and St. Lucie waters are based upon the change to the total area with depth between 2.6 and 9.2 ft deep. Since the existing coverage of SAV is much smaller than the total area with optimum depth, and the analysis does not directly take into account salinity or water quality, it is possible that this analysis under-estimates benefit loss in the Caloosahatchee and St. Lucie basins.

Scientific unknowns also present a significant source of uncertainty in the effects and timing of impacts from SLR. It is unclear how quickly and successfully natural area habitat and species can transition or adapt to the range of potential future conditions anticipated due to ongoing and accelerating global climate change. This analysis assumed that estuarine habitat quantity remained unchanged as sea level increases. Topographic and Bathymetric analysis presented here shows that for moderate SLR of up to two feet, available estuarine acreage increases substantially. However, the functionality of this new estuarine acreage is unknown and it will depend upon factors such as water quality that are not incorporated into this analysis.

The distribution of water between the natural system and the developed areas is assumed to be constant in this analysis in part because water made available for the natural system by CEPP will be reserved as part of the project authorization process. However, increased sea level is likely to cause increased saltwater intrusion into coastal freshwater supply wells fields. In response, urban and agricultural water users may seek to shift water deliveries from the natural system (Everglades National Park) towards eastern portions of Miami-Dade and Broward Counties. The degree to which project water reservations will protect natural system water supplies has not been tested in this manner so it presents a risk to project benefits.

Finally, climate change impacts such as changes in temperatures and rainfall patterns, plus the increasing frequency or intensity of extreme weather events (droughts, floods, storms), will make drought conditions more prevalent and require the addition of additional flood protection measures. Decreased water availability and enhanced flood protection are likely to reduce expected project benefits.

## I.5 ADAPTIVE MANAGEMENT

To reduce the risk associated with implementing the project, flexibility in the design and operation of features can be incorporated into the project during the planning phases. Also features planned and operated for one purpose can be repurposed as SLR begins to affect water management needs into the future. For instance, the CEPP project will allow much more water to be sent south from Lake Okeechobee to the Everglades. At present the primary function of this additional water is increased hydroperiod within the Everglades Marsh. As the MTL increases, this additional water will provide a buffer of freshwater that will limit salinity related impacts to freshwater wetland vegetation, reduce peat soil degradation, and impede saltwater intrusion into the groundwater aquifer. At some point, the preservation of freshwater wetland habitat within Everglades National Park may require physical intervention particularly within Shark River Slough. One adaptation plan might be to increase the amount of water sent from Lake Okeechobee south. This would likely require additional congressional authorization to either alter the Herbert Hoover Dike or to provide additional water storage capacity and treatment within the Everglades Agricultural Area. One adaptive manage strategy may be to construct a shallow sand berm across Shark River Slough for the purpose of limiting northward tidal flows into peat soil marsh areas. Another adaptive management strategy to address sea level rise may be to use Tamiami Trail and the L-29 levee as a tidal barrier to prevent saltwater intrusion into WCA-3A/B. This would effectively reverse some of the decompartmentalization work included in the CEPP. To maintain estuarine habitat, some limited human assistance may be very helpful, such as planting mangroves in salinity impacted areas upslope to help tidal ecosystems adapt more successfully to higher rates of sea level rise. The purchase of additional uplands for habitat migration would not likely be proposed as an adaptive measure for this project at least within the Everglades Protective Area since most of the project lands affected by future SLR impacts are already in public ownership.

## I.6 CONCLUSION

The effects of sea level rise have been analyzed per (EC 1165-2-212). This analysis looked at the effect of SLR on the benefits predicted for the selected alternative (ALT4R2). The results indicate that within the 50-year planning horizon the average annual net project benefits are likely to be reduced by less than 8 percent in comparison to the projected net annual average project benefits estimated assuming no sea level rise. This relatively moderate decrease in average annual project benefits occurs largely because of closely matching habitat losses under the FWO condition. However, when considering total freshwater wetland habitat, sea level rise will substantially reduce this habitat area. For instance, under the high rate sea level rise scenario, total project area habitat function will be reduced by 8, 21, and 37 percent at the 20, 50, and 100 year timelines, respectively. The total habitat function is significantly higher with CEPP in place under any SLR scenario and timeframe when compared to the FWO condition. The ability of the CEPP project to provide substantially higher habitat functionality when compared to the FWO is partly a result of the increased freshwater flows that reduce the loss of freshwater habitat within Everglades National Park.

There is no doubt that SLR over the last 100 years has impacted Shark River and Taylor Sloughs, the southern glades, and the downstream nearshore estuarine habitat. This is evident by the landward migration of the white zone habitat and the abandonment of farming activities in the extreme southern glades. Water management alterations such as the C-111 and L-32N canals have likely exacerbated the impact of past SLR by substantially reducing surface and groundwater deliveries to Taylor Slough and the southern glades. Relevant ecological literature as well as best professional judgment supports the conclusion that augmenting flows to Shark River and Taylor Slough is critical to maintaining the sawgrass habitat and nearshore estuarine salinity conditions downstream. Given the possibility of peat decomposition caused by landward migration of the salt habitat front, it is critical to the Shark River and Taylor Slough ecosystem that additional freshwater flows are distributed south along Tamiami Trail. Without augmenting Shark River and Taylor Slough flows, it is apparent that the future without project scenario will result in accelerated loss of the functional coastal mangrove ecotone and sawgrass habitat under low and intermediate SLR projections as compared to the selected project scenario.

The most significant uncertainties associated with the SLR impact projections provided here are: 1) the lag time between when freshwater wetlands become substantially impaired due to salinity impacts and when replacement estuarine habitat becomes fully productive, and 2) the degree to which project related water reservations will protect natural system water supplies given SLR related demand from the developed areas.

## I.7 REFERENCES

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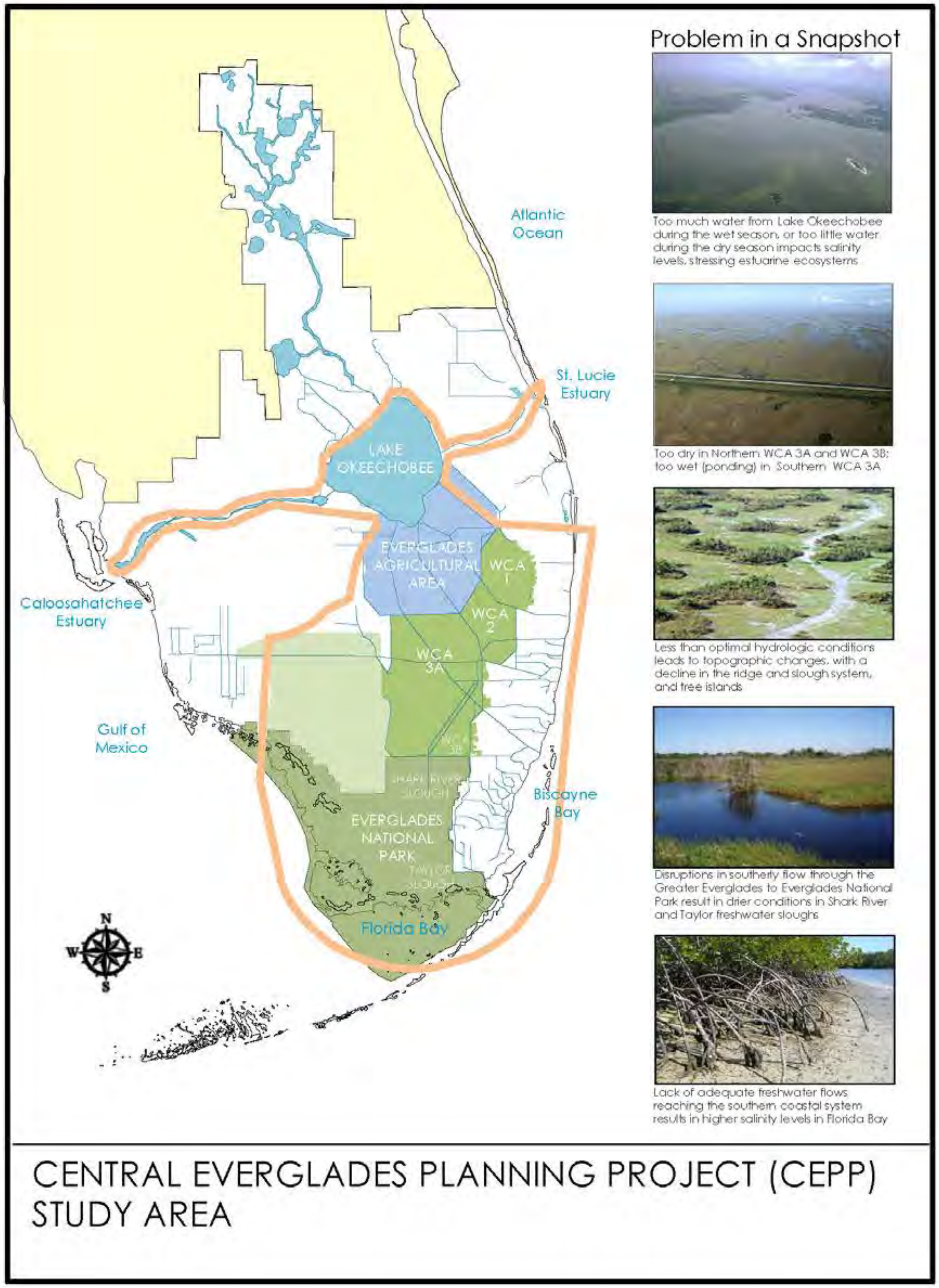


**Figure I-1. CEPP Alternative Project Boundaries**

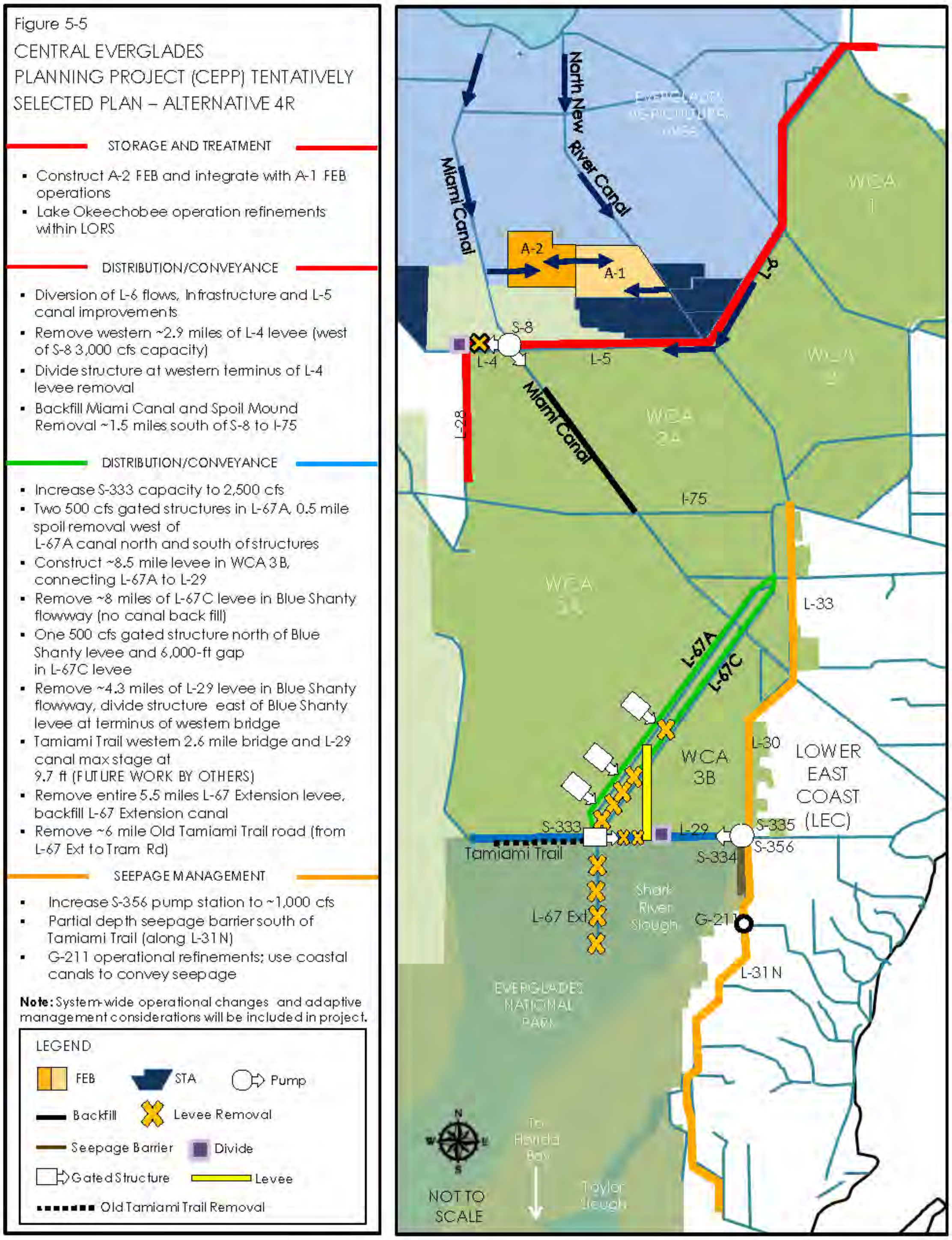


**Figure I-2. CEPP Alternative 4R and Alternative 4R2 (Selected Plan) Project Components**


**Figure I-3. 2011 Oyster and Seagrass Habitat within the Western Portion of the St. Lucie Estuary**

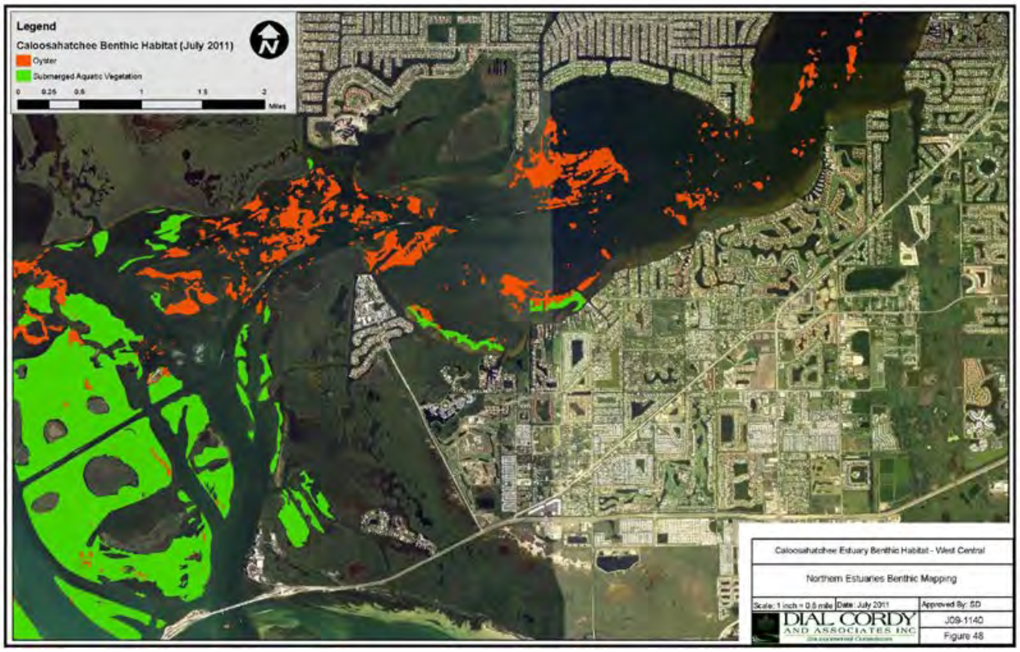


**Figure I-4. 2011 Oyster and Seagrass Habitat with the Lower Portion of the Caloosahatchee River Estuary**

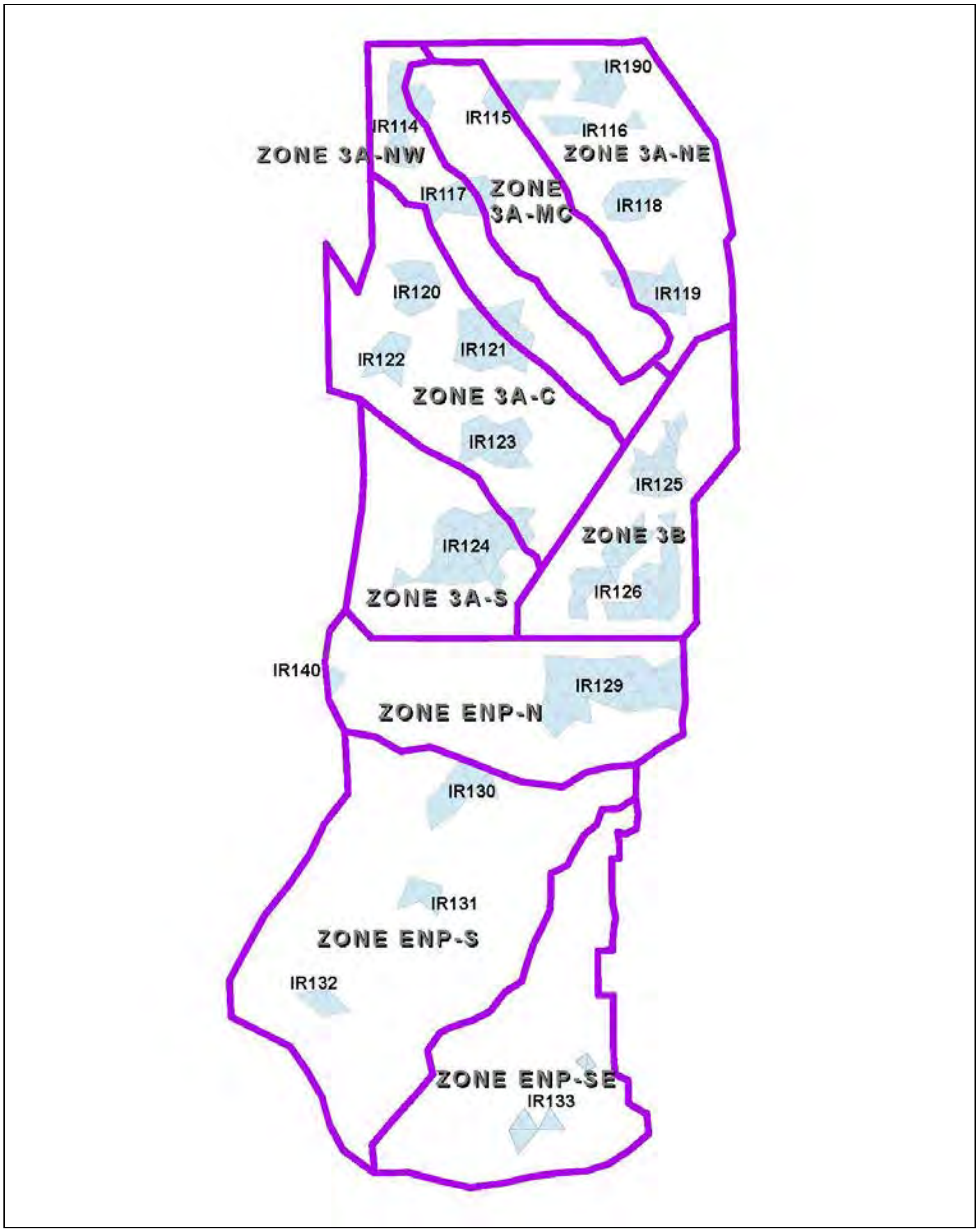


**Figure I-5. Freshwater Habitat Zones and Indicator Regions for the CEPP Benefit Evaluation**

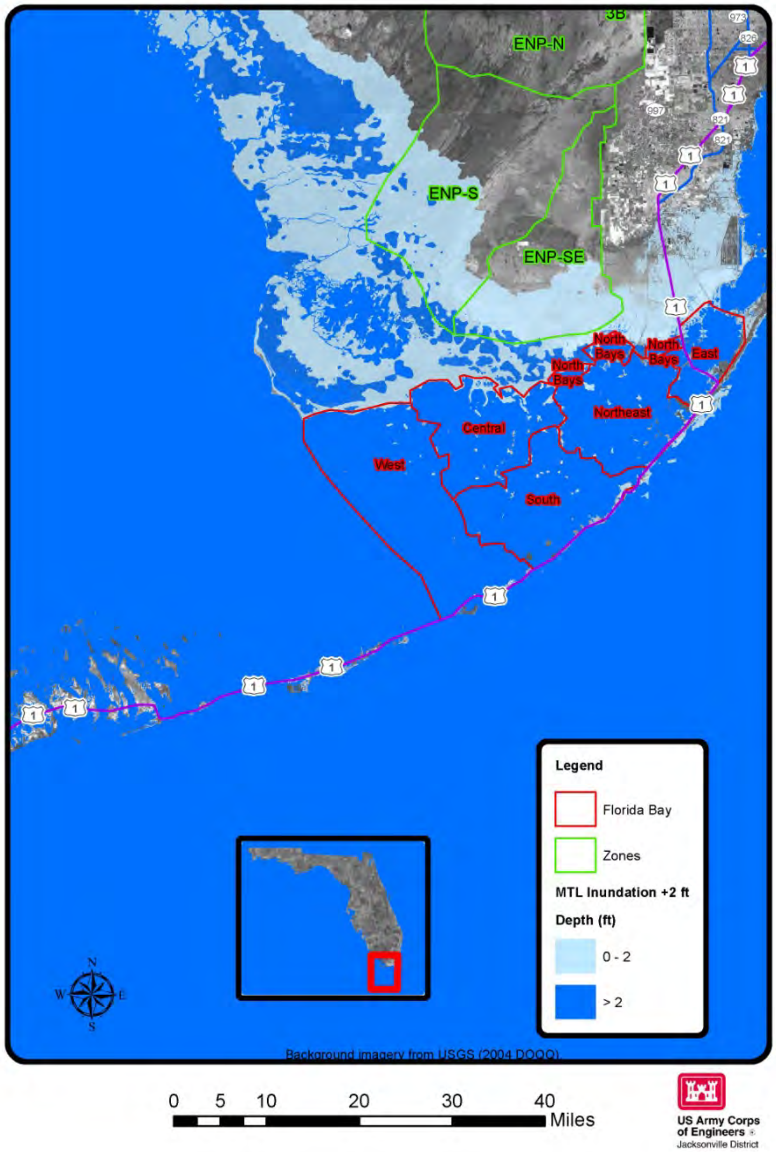


**Figure I-6. Existing Conditions Showing CEPP Sub-Regional Boundaries for Nearshore Habitat**

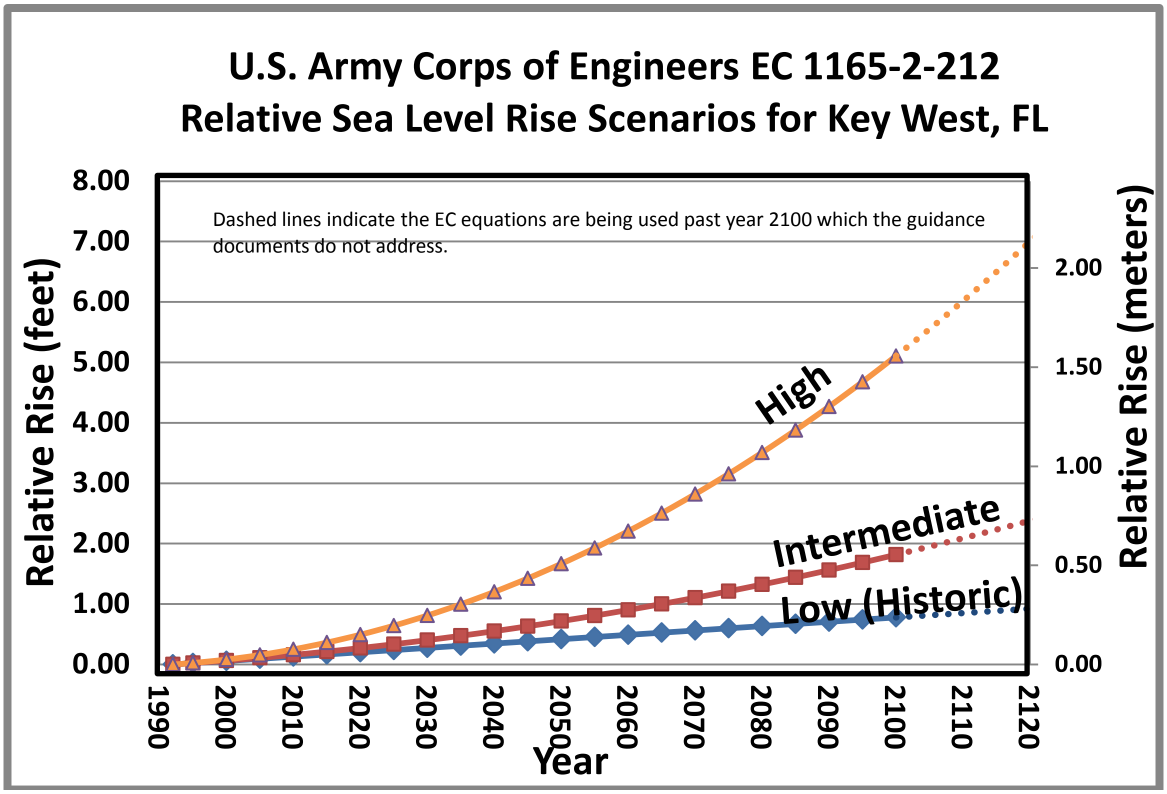


**Figure I-7. Projected Sea Level Rise (1922-2113)**

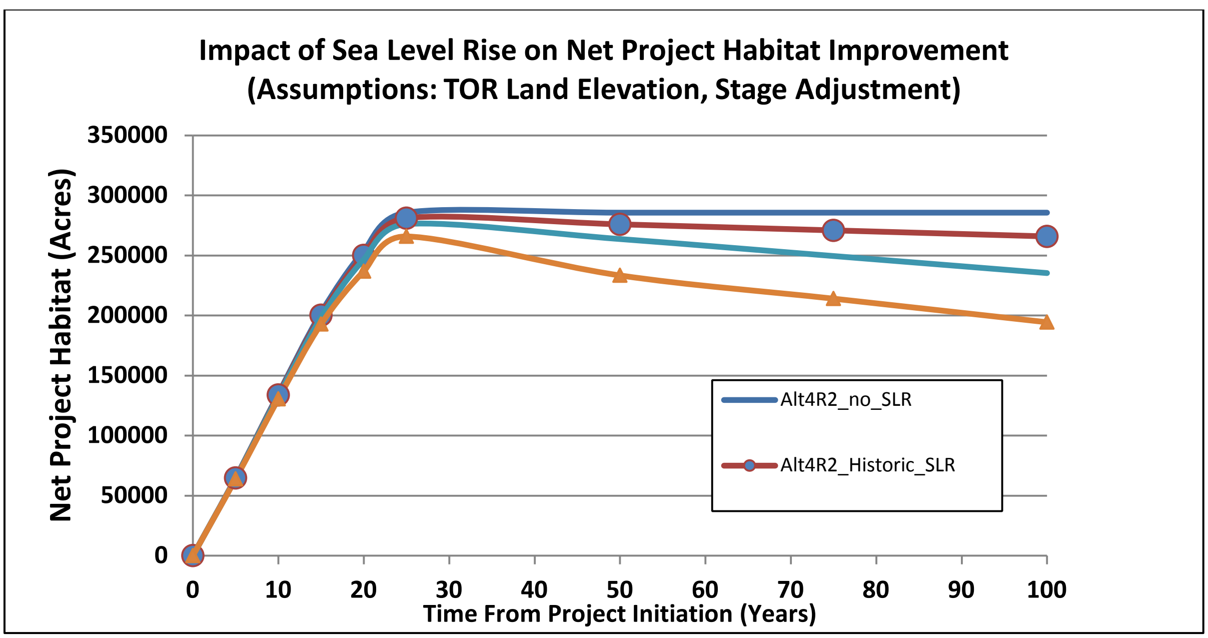


**Figure I-8. Net Project Habitat Units for ALT 4R2 Assuming Peat Loss and Project Related Changes to Hydrology**

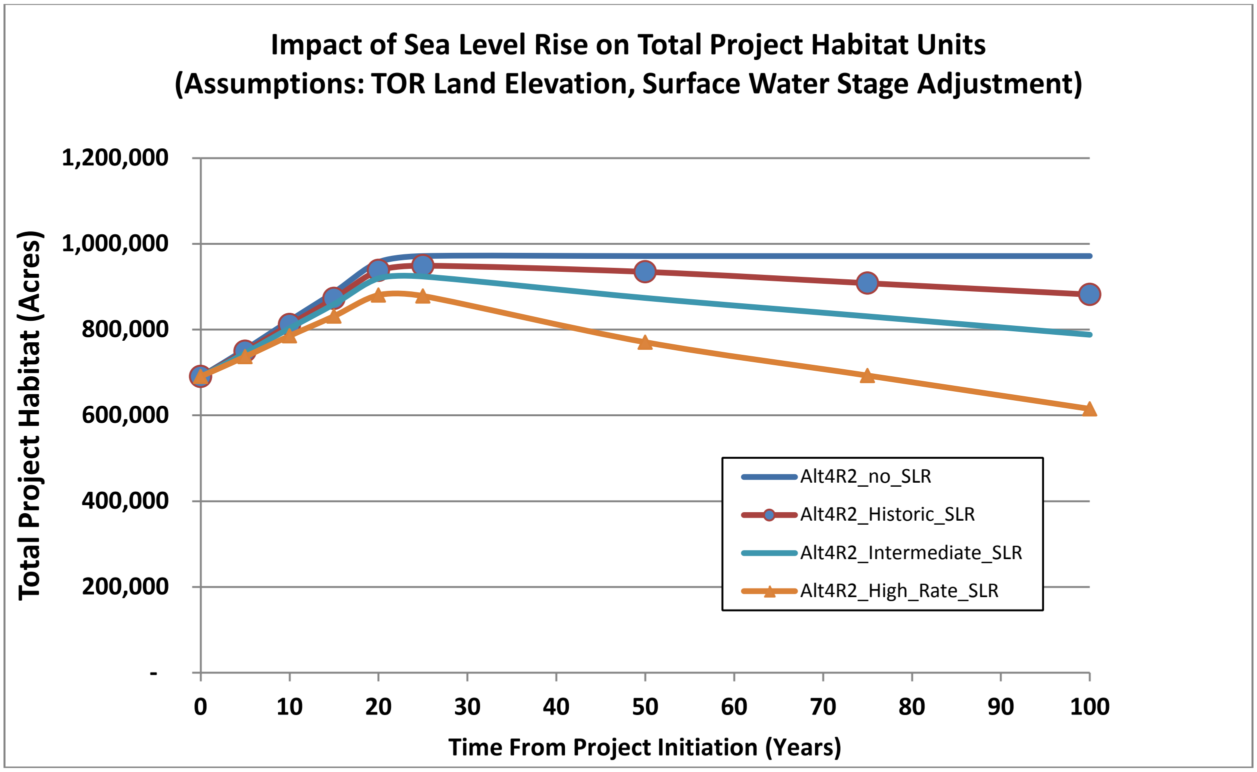


**Figure I-9. Total Habitat Units for ALT 4R2 Assuming Peat Loss and Project Related Changes to Hydrology**

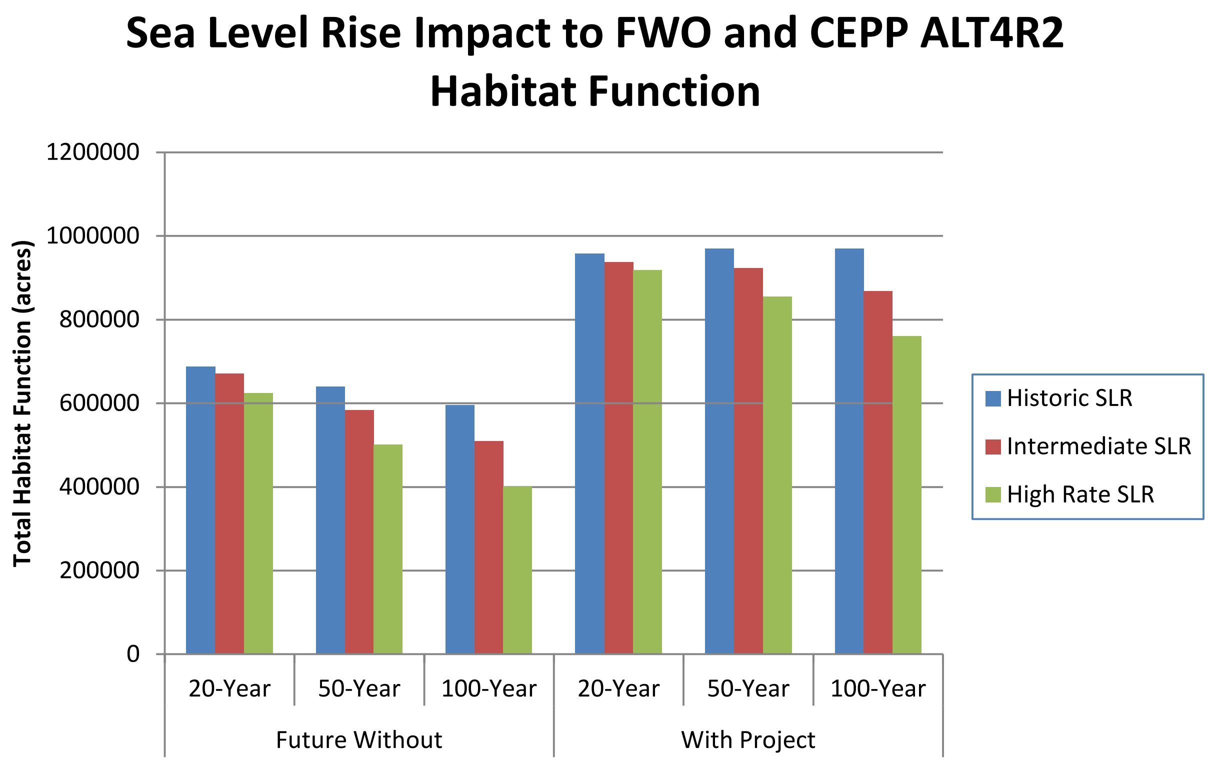


**Figure I-10. Total Habitat Function for FWO and CEPP ALT4R2 Conditions As Impacted by Sea Level Rise**

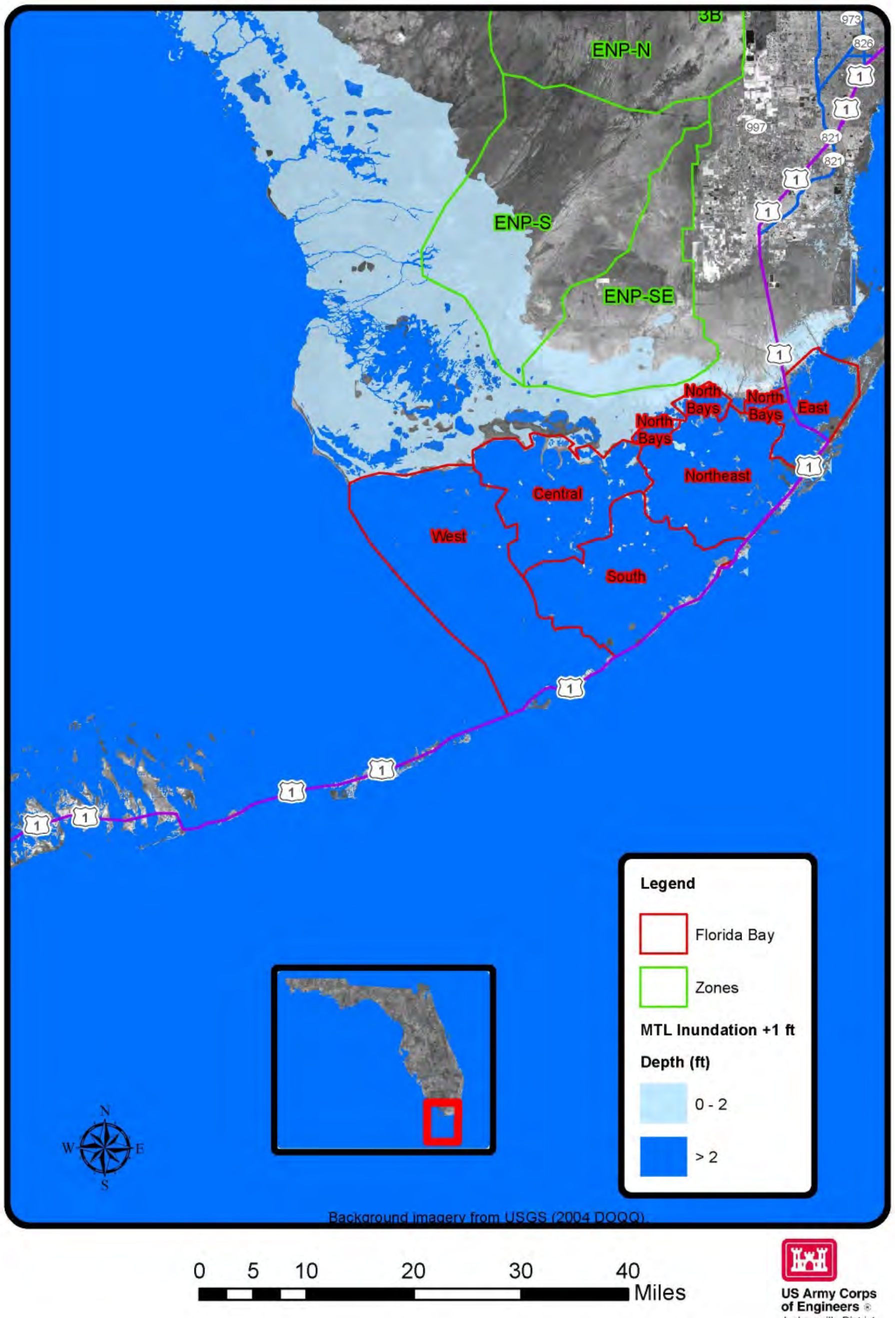


**Figure I-11. Alternative 4R with 1' SLR, Assuming Existing Topography for the Southern Portion of the Project**

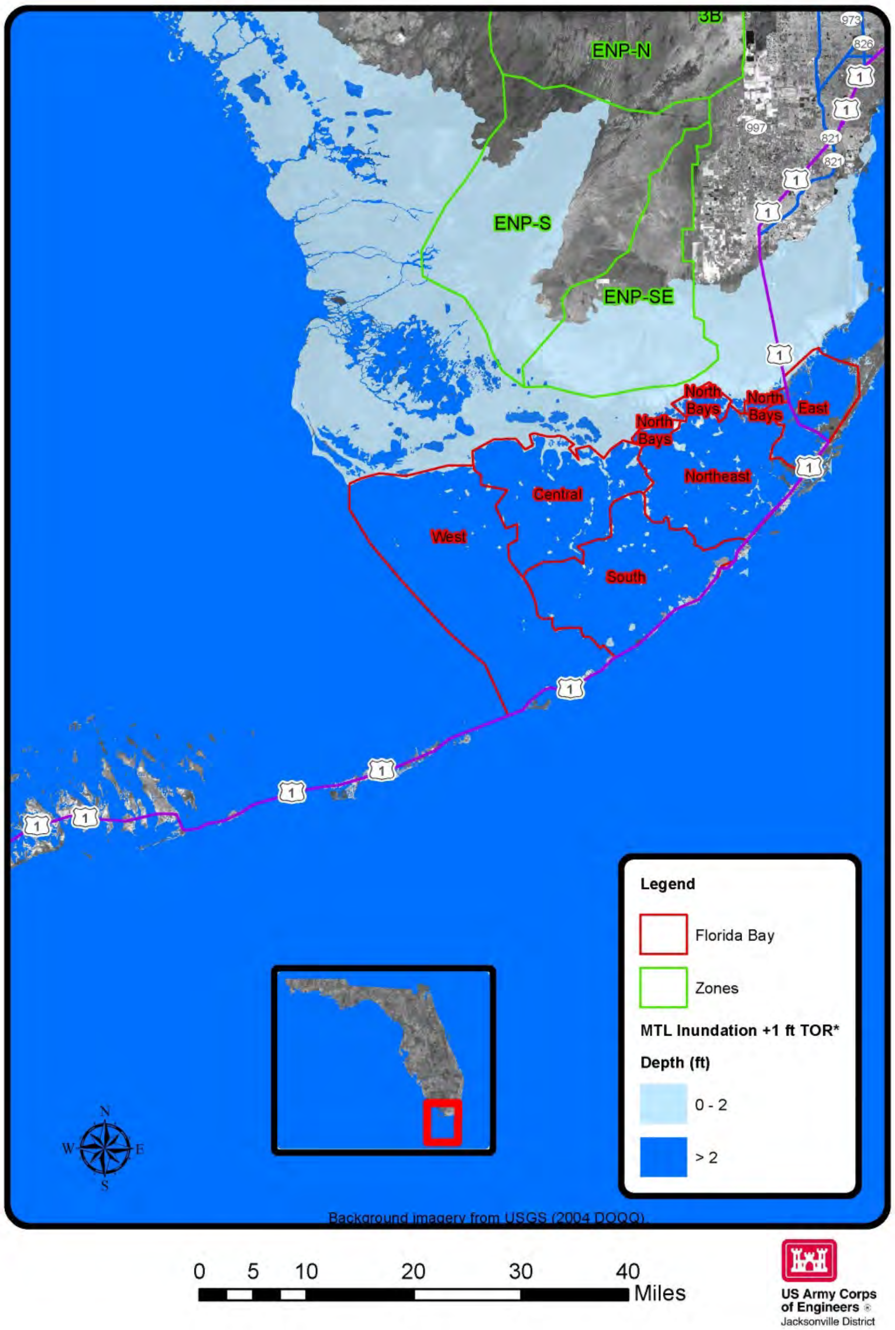


**Figure I-12. Alternative 4R with 1' SLR, Assuming Complete Loss of Peat Soils, for the Southern Portion of the Project**

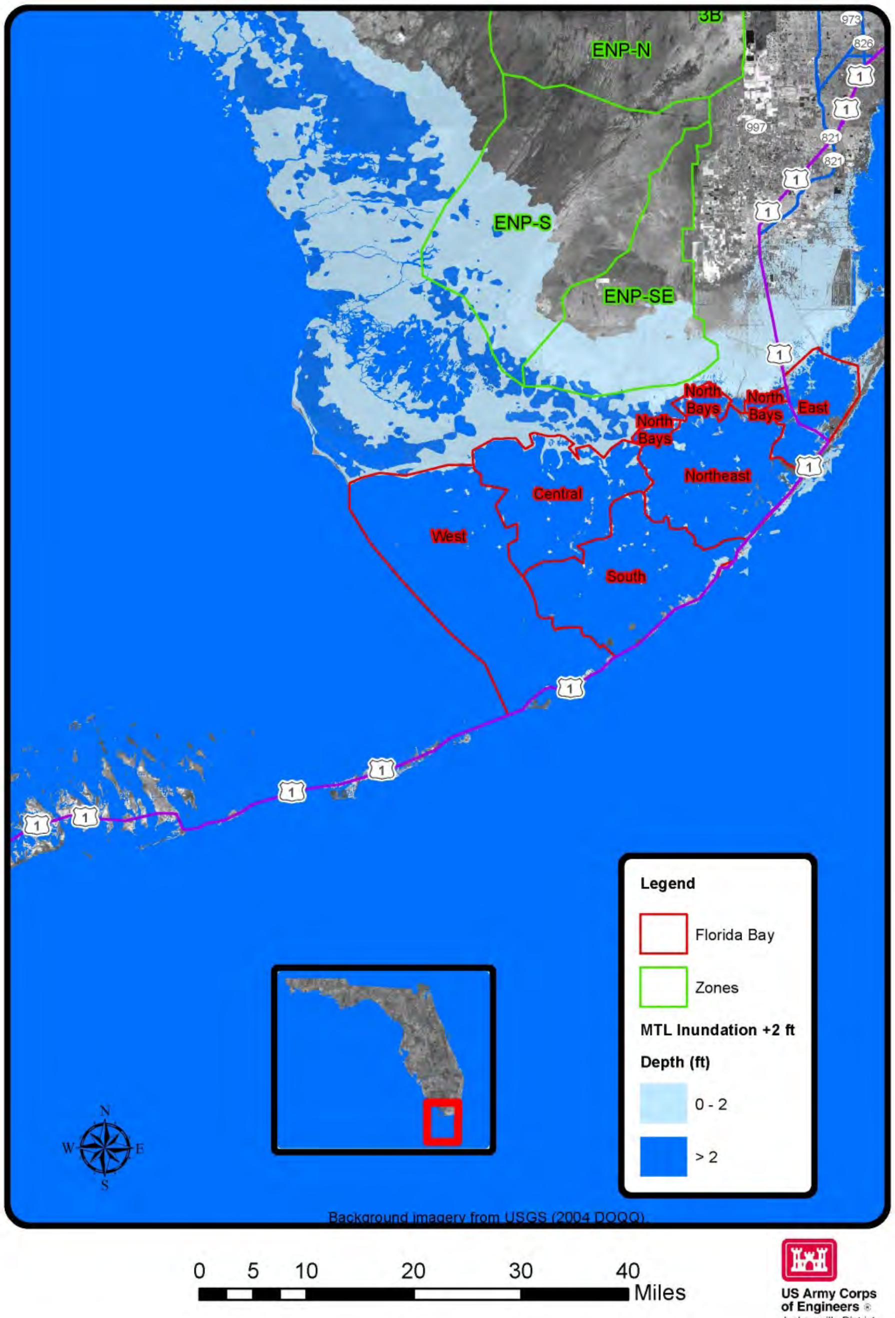


**Figure I-13. Alternative 4R with 2' SLR, Assuming Existing Topography, for the Southern Portion of the Project**

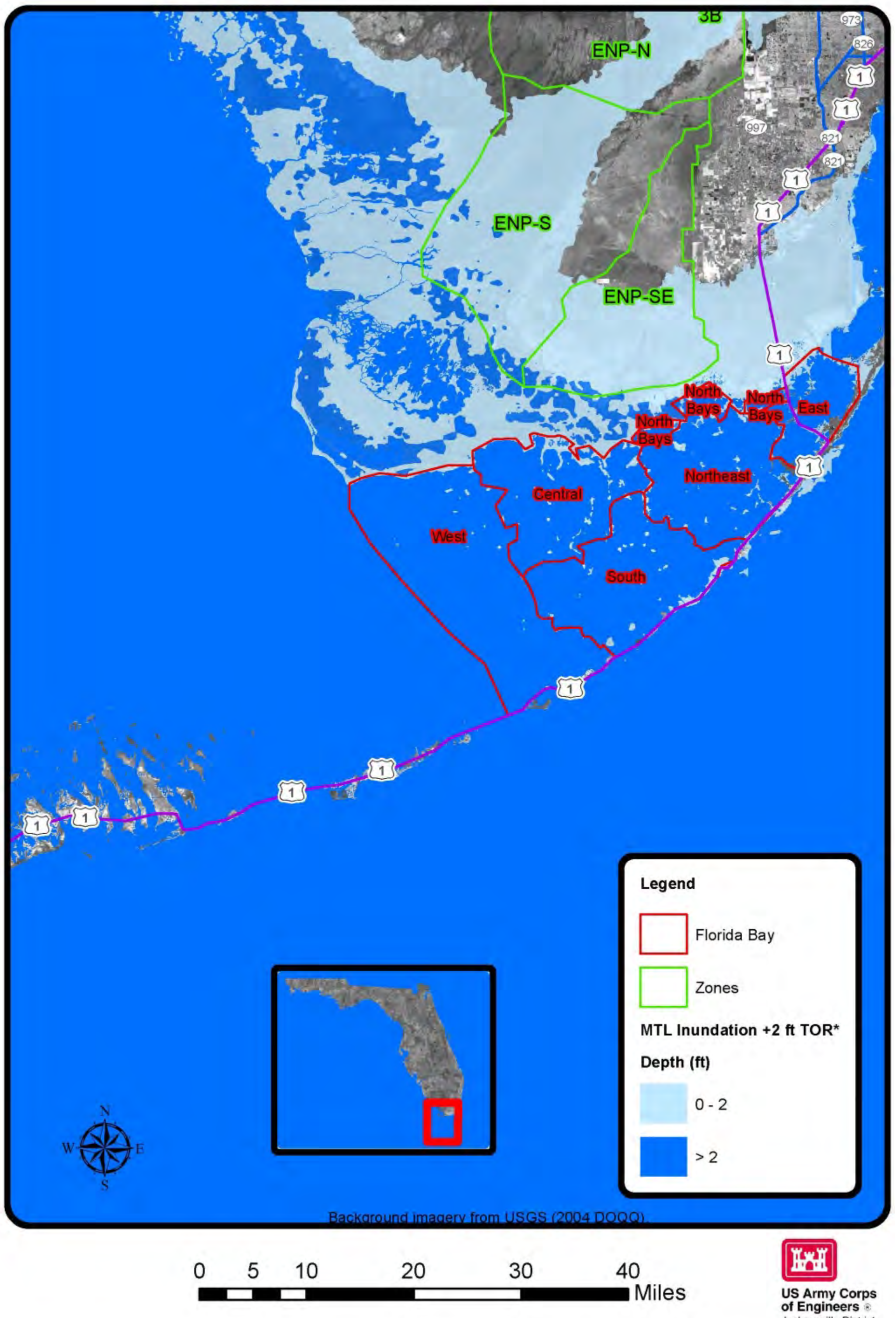


**Figure I-14. Alternative 4R with 2' SLR, Assuming Complete Loss of Peat Soils, for the Southern Portion of the Project**

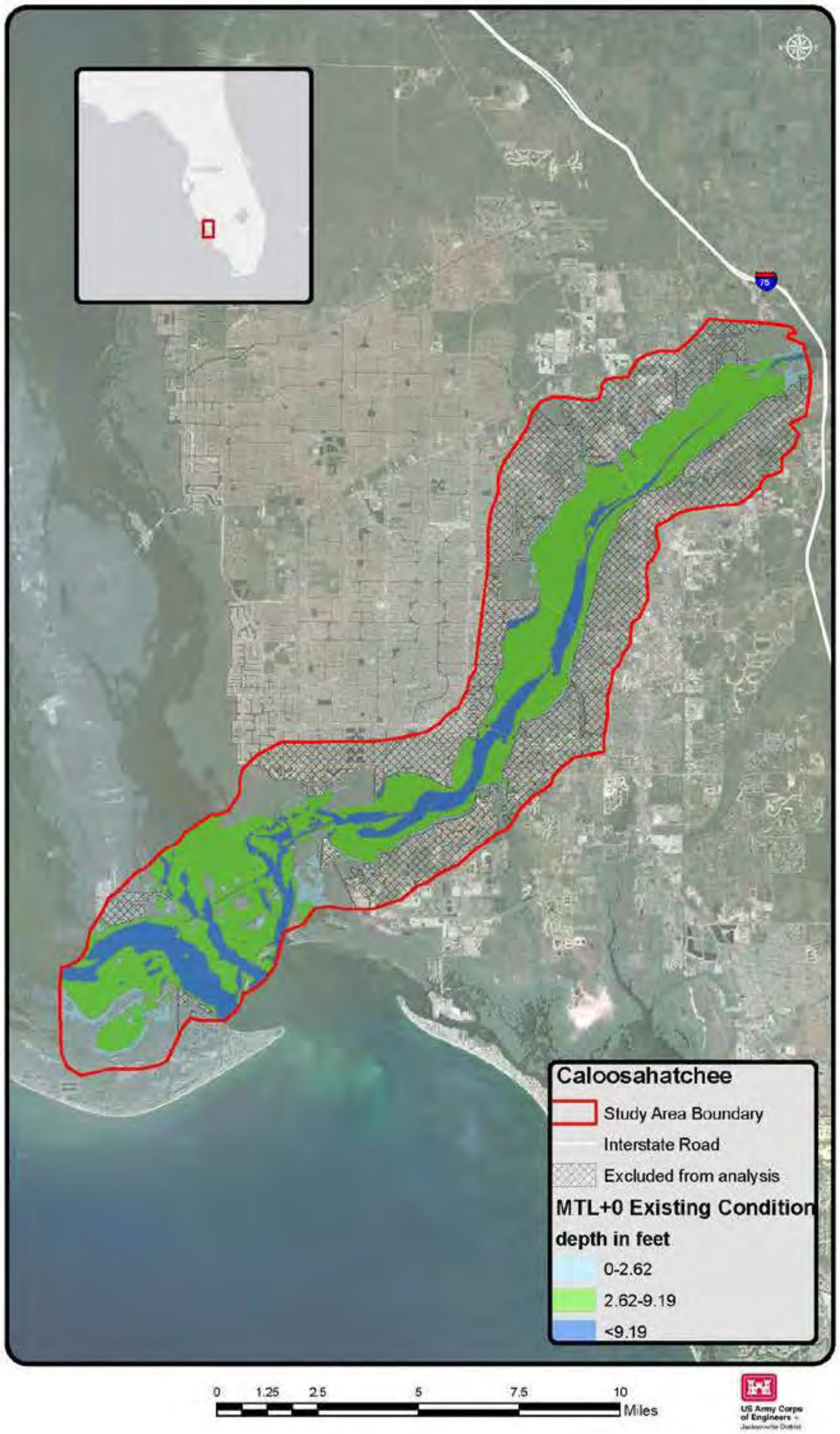


**Figure I-15. Potential Submerged Aquatic Vegetation Habitat in Caloosahatchee Estuary with 0 ft of Sea Level Rise**

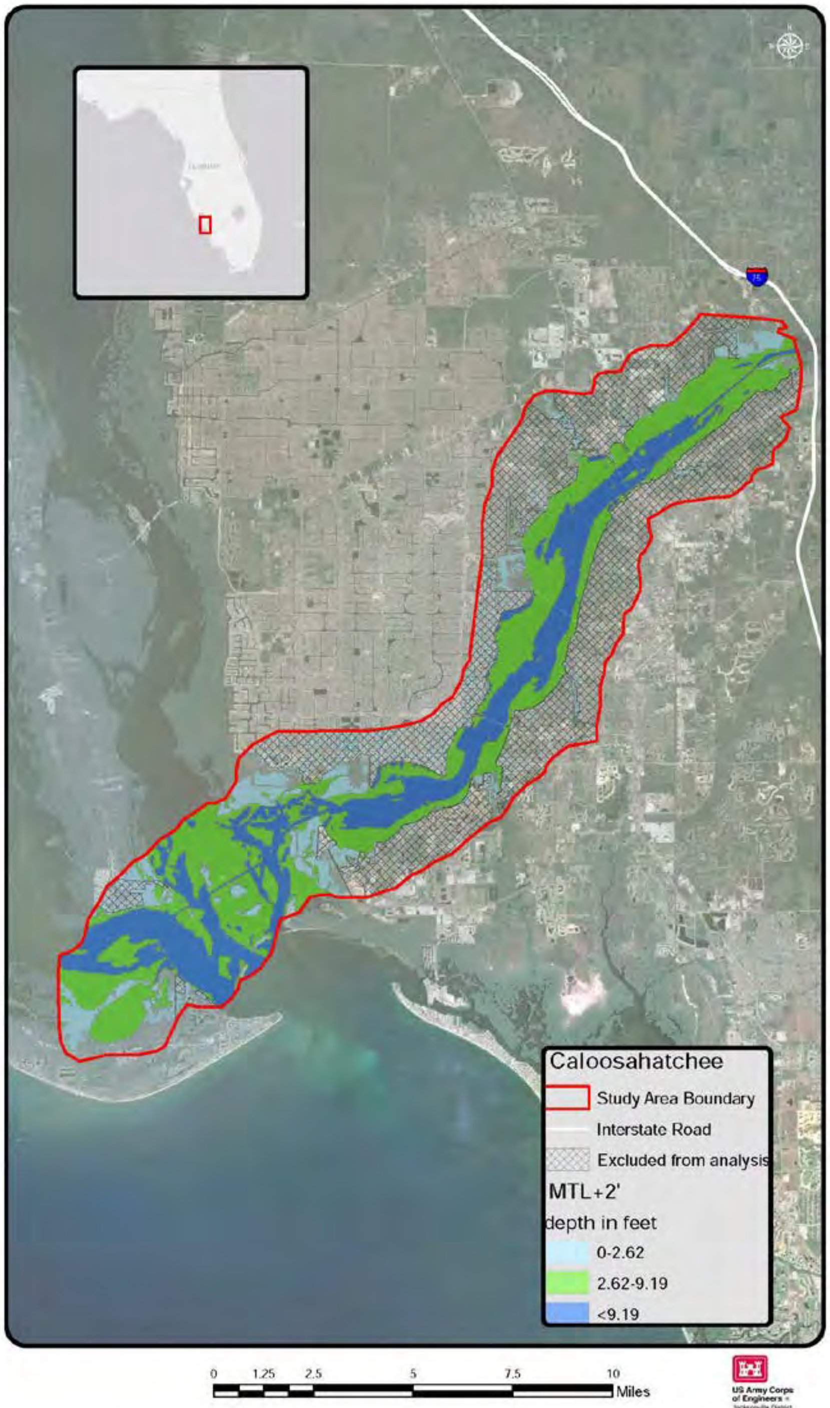


**Figure I-16. Potential Submerged Aquatic Vegetation Habitat in Caloosahatchee Estuary with 2 ft of Sea Level Rise**

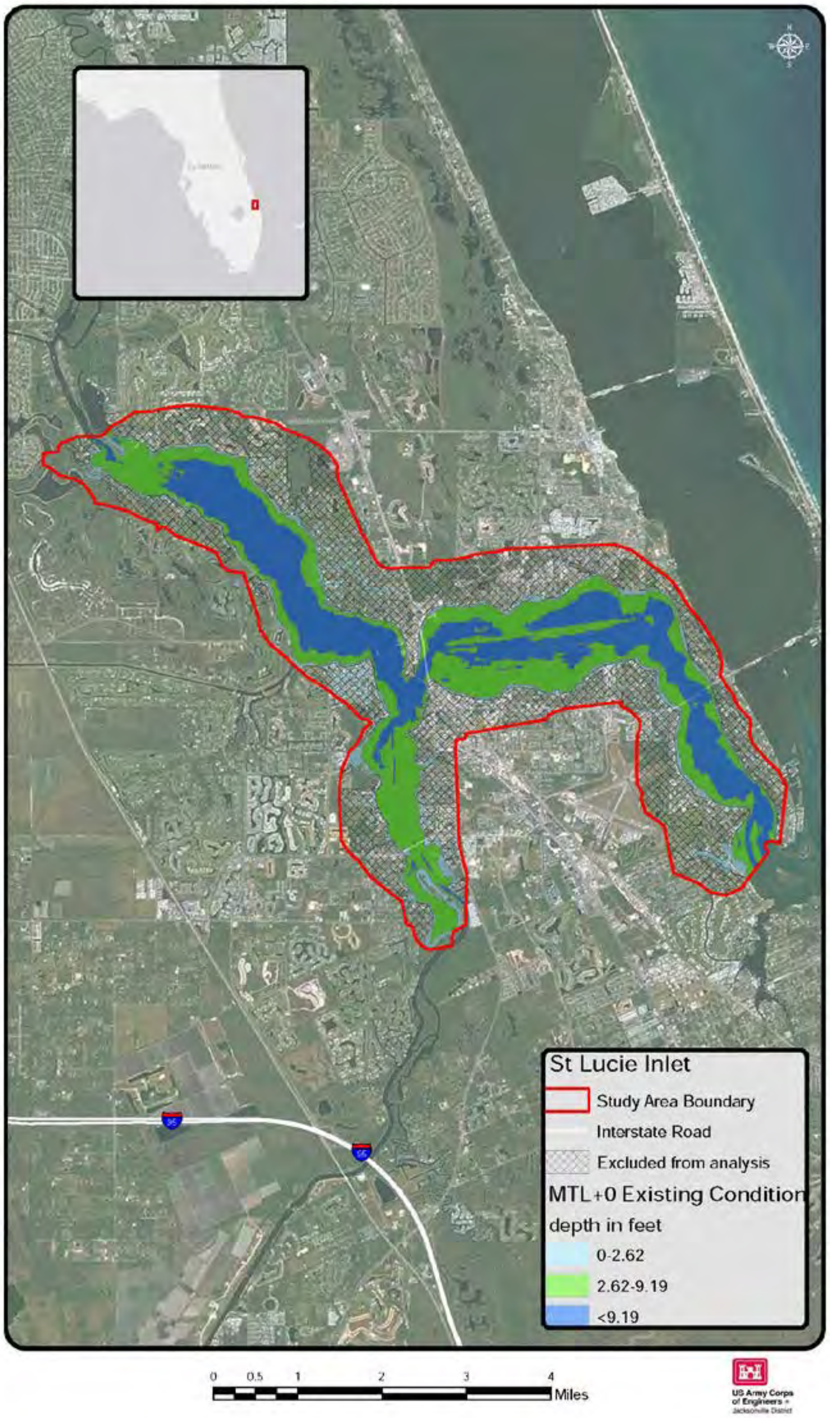


**Figure I-17. Potential Submerged Aquatic Vegetation Habitat in St. Lucie Inlet with 0 ft of Sea Level Rise**

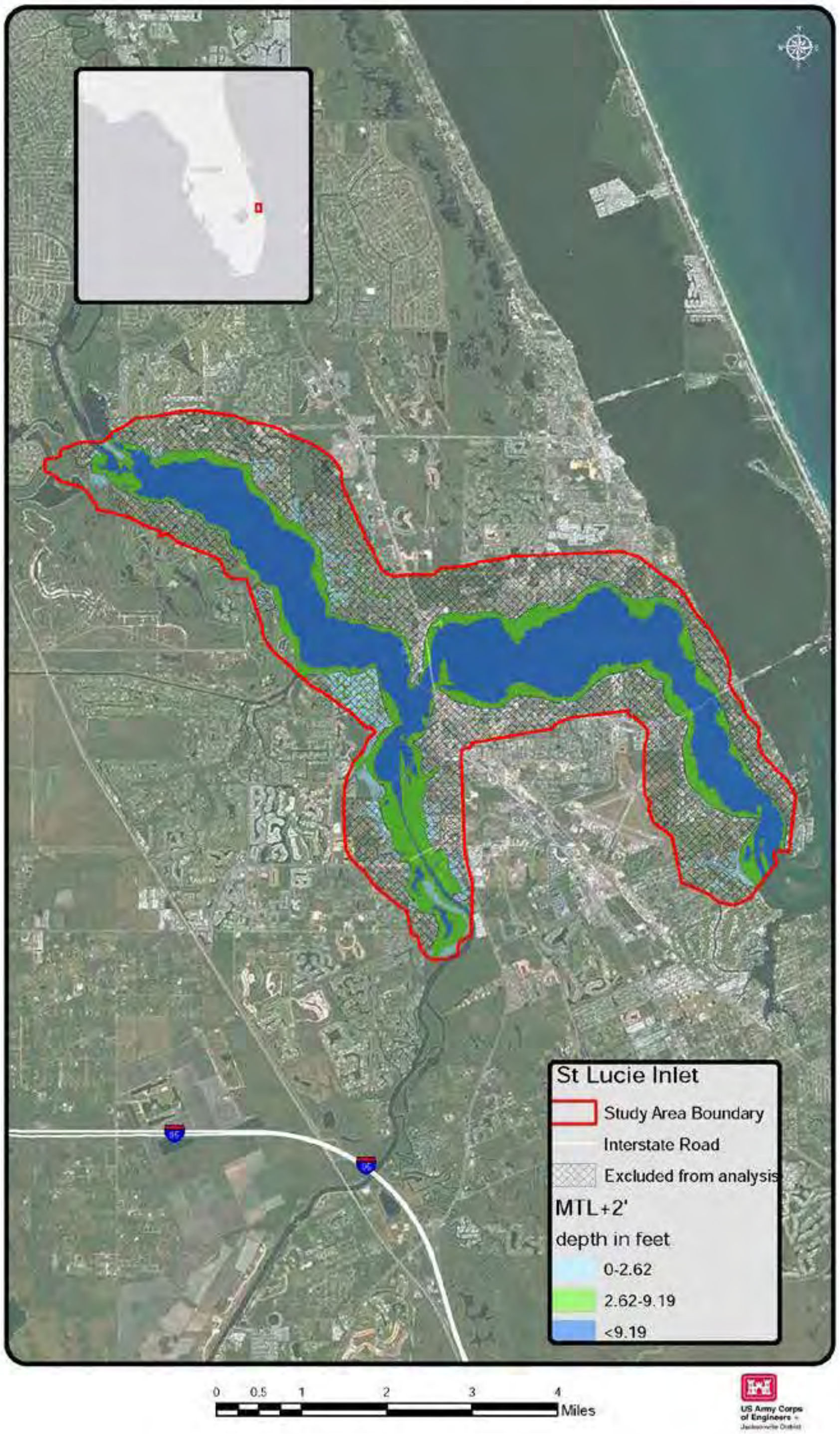


**Figure I-18. Potential Submerged Aquatic Vegetation Habitat in St. Lucie Inlet with 2 ft of Sea Level Rise**